SEMI-ANNUAL REPORT

NASA CONTRACT NAS5-31368

For
MODIS Team Member: Steven W. Running
Assoc. Team Member: Ramakrishna R. Nemani
Software Engineer: Joseph Glassy
15 January , 1999

OBJECTIVES:

We have defined the following near-term objectives for our MODIS contract:

-   Organization of a global biospheric monitoring network with collaborating U.S. and international science agencies for EOS Land validation.

-   Deliver at-launch software for our MODIS products, #15 Leaf Area Index and Fraction Absorbed Photosynthetically Active Radiation, and #17 Daily Photosynthesis - Annual Net Primary Production.

-   Develop MODIS applications products for national fire management.

The NTSG lab currently employs:
Dr. Steven Running, Director and Professor,
Dr. Ramakrishna Nemani, Research Assoc. Professor
Dr. Lloyd Queen, Associate Professor
Dr. John Kimball, Postdoctoral Research Associate
Dr. Swazik Laguette, Postdoctoral Research Associate
Dr. Peter Thornton, Postdoctoral Research Associate
Mr. Joseph Glassy, Software Engineer
Mr. Petr Votava, Programmer
Mr. Saxon Holbrook, Computer Systems engineer
Ms. Galina Churkina, PhD student
Mr. Mike White, PhD student
Ms. Alisa Keyser, PhD student
Mr Carl Seilstad, PhD student
Mr Jim Plummer, PhD student
Ms. Youngee Cho, Office Manager

All of these members contribute to certain aspects of our MODIS work.

ACTIVITIES OF SWRunning (MODIS Team Member)

WORK ACCOMPLISHED:
My most significant activity of the last 6 months is completion of revisions of a major planning paper for global biospheric monitoring that will be part of a Special Issue of Remote Sensing of Environment. The abstract is copied below.

A GLOBAL TERRESTRIAL MONITORING NETWORK INTEGRATING TOWER FLUXES WITH ECOSYSTEM MODELING AND EOS SATELLITE DATA

S.W. Running[1], D. D. Baldocchi[2], W. B. Cohen[3], S.T. Gower[4], D. P. Turner[3], P. S. Bakwin[5], K. A. Hibbard[6]

ABSTRACT
Accurate monitoring of global scale changes in the terrestrial biosphere has become acutely important as the scope of human impacts on biological systems and atmospheric chemistry grows. For example, the Kyoto Protocol of 1997 signals some of the dramatic socioeconomic and political decisions that lie ahead concerning CO_2 emissions and global carbon cycle impacts. These decisions will rely heavily on quantitatively accurate measures of global biospheric changes of many dimensions (Schimel 1998, IGBP TCWG 1998). An array of national and international programs have inaugurated global satellite observations, critical field measurements of carbon and water fluxes, and global model development for the purposes of beginning to monitor the biosphere. The detection of interannual variability of ecosystem fluxes and of longer term trends will permit early indication of fundamental biospheric changes which might otherwise go undetected until major biome conversion begins. This paper describes a blueprint for more comprehensive coordination of the various flux measurement and modeling activities into a global terrestrial monitoring program that will have direct relevance to the political decision making of global change.

EOS-IWG
I participated in a number of projects to develop both MODLAND, and more generally EOS Land product validation. These projects are in many ways interrelated, and their efficiency is maximized by regular coordination. Following are brief summaries of current activity for:

BIGFOOT = a field ecological measurement program in the US
GTOS-NPP = a global program related to BIGFOOT for GTOS
FLUXNET = a global array of CO2 and H20 flux towers
PIK-NPP = a global NPP model intercomparison
VEMAP = a US based ecological model intercomparison

BIGFOOT -- Characterizing Land Cover, LAI and NPP at the Landscape Scale for EOS/MODIS Validation:

The BigFoot project has now started as a part of the EOS Validation program. Four sites have been selected for initial field activity, all FLUXNET participators. The BIGFOOT measurement protocol is the guide for the international GTOS-NPP project. So BIGFOOT scaling principles will be propogated globally.

The project website is at:
http://www.fsl.orst.edu/larse/bigfoot/slide1.html

FLUXNET

The FLUXNET program is maturing rapidly as the cornerstone of EOS Land validation, website at:
http://daacl.ESD.ORNL.Gov/FLUXNET/
There are now 80 sites globally, and substantial international coordination. This network is ready for EOS launch now.

THE GAIM-NPP model intercomparison study

We co-authored the following papers for a special issue of Global Change Biology, now "in press".
Galina Churkina and Steven W. Running; Contrasting climatic controls on the estimated productivity of global terrestrial biomes; Ecosystems (1998) 1: 206-215.

Galina Churkina, Steven W. Running, Annette L. Schloss and the participants of "Potsdam '95"; (1999) Comparing global models of terrestrial net primary productivity (NPP): The importance of water availability. Global Change Biology. (in press).

Wolfgang Cramer, David W. Kicklighter, Alberte Bondeau, Berrien Moore III, Galina Churkina, Bernard Nemry, Anne Ruimy, Annette L. Schloss and the participants of "Potsdam '95", Comparing global models of terrestrial net primary productivity (NPP): Global Change Biology. (in press).

Galina Churkina and Steven W. Running, (1999) Investigating the balance between timber extraction and the productivity of global coniferous forests. Climatic Change (submitted).

Abstract
Measurements of extracted timber and modeled forest productivity are used to investigate relationship between forest harvested by people and forest natural productivity. At this stage, we confine our analysis to coniferous forests and countries that have coniferous forest on their territories. Annual roundwood (unprocessed primary wood) production from the database ofFood and

Agriculture Organization (FAO) is used as an approximation of annual timber harvest by country. Annual stem primary productivity of coniferous forests is estimated using the BIOME-BGC model. Based on the current rates, we extrapolate annual timber extraction for each country for the next 15 years. Then, on a country basis, we relate the amount of extracted timber to the estimated forest stem productivity assuming that coniferous forest area would stay unchanged for the next 15 years. We discuss the natural capacity of coniferous forests to sustain increasing wood extraction by people and identify countries where wood shortages may occur in the future if the timber products continue to be consumed at the current rates.

Global Climate and Terrestrial Observing Systems (GCOS/GTOS)

The GTOS-NPP project is being initiated to provide coordinated global measurements of landocver, LAI and NPP for EOS validation. Reports from the ILTER office are that international field sites are slow in joining the program. Until real EOS data is available as an inticement, I expect this reluctance to continue.

VEMAP - Vegetation ecosystem modeling and analysis project

VEMAP is a project to intercompare leading biogeography and biogeochemistry models in the US for global change and EOS research programs. VEMAP has a homepage at:

http://www.cgd.ucar.edu:80/vemap/

VEMAP Phase II is currently building the datasets and initialization files for transient simulations of climate and vegetation response for the continental United States. These new simulations will be executed within the next 6 month period.

GLOBE

The University of Montana has been selected as a GLOBE regional Training Center. The following description of university activity includes substantial GLOBE involvement.

University of Montana International EOS Natural Resource Training Center

The University of Montana initiated an EOS training center for natural resource managers in October 1998. I had responsibility to write the proposal, and integrate it with our wider EOS and MODIS research activity. The following text summarizes the goals of this Center

Executive Summary

With the launch of NASA's Earth Observing System (EOS) satellites in mid-1999, the extent and timing of remotely sensed data will reach new levels of regular full earth coverage. Numerous well-studied algorithms will turn the raw information

of basic remote sensing into application products covering the globe on a daily to weekly time step. The International EOS Natural Resources Training Center (IENRTC) is a program designed to meet the challenges of educating the public about NASA=s newest remote sensing applications. To address the needs of a large and diverse user group, the EOS International Training Center will utilize the skills and resources of faculty and staff in the School of Forestry and the School of Education at the University of Montana as well as those of peers at the Universities of Alaska, Idaho, and Missouri. This coordinated effort will allow educational relationships to build between the School of Forestry and the School of Education to meet the diverse needs of Natural Resource Managers and Personnel and the K-12 educational community. Within the School of Forestry, the *Numerical Terradynamic Simulation Group* along with the *Bolle Center for People and Forests* will work to acquire, process, and present EOS data in a relevant and meaningful manner to natural resource managers. The Northern Rockies Sky School in the School of Education will plan professional teacher training and teacher inservices to begin to demonstrate the concepts of remote sensing along with basic GIS applications into the classroom environment. Using EOS data products provided by NTSG and supplementing already widely accepted NASA educational programs (e.g., GLOBE), the IENRTC will introduce the latest remote sensing concepts to the next generation of users.

Project Objectives:

To produce enhanced EOS land application products for natural resource management.

To train natural resource land managers to find, acquire, analyze and interpret EOS data to enhance the utility of EOS in land management

To identify, develop and disseminate EOS-related curricula for K-12 education.

To provide professional development of K-12 preservice and inservice teachers.

NASA EOS and Related MEETINGS ATTENDED (SWR)

> EOS-SEC Meetings, October, December, 1998
> Carbon Cycle Science Workship, Westminster, CO, Aug. 1998
> NASA EOS Second Phase Planning Workshop, Wash DC, Aug. 1998
> Climatic Research Committee meeting, Wash DC, Sept. 1998
> NASA EOS IWG.EMDI meeting, Durham, NH, Oct. 1998
> NCAR-Global Change Science Requirements for Longterm Archives and Data   Continuity, Boulder, CO, Oct. 1998
> VEMAP meeting, Tucson, AZ, Oct. 1998

Activities of Lloyd Queen

Progress Report on Remote Sensing for Fire Management

We are taking a major applications initiative in developing uses of MODIS Land products for Fire Management. The U.S.Forest Service has responsibility across all federal land management agencies for wildland fire mangement. So we are developing multiple collaborations with Forest Service fire scientists and managers to use future MODIS products. Research on the two fire products (fire location and drought/fire index) has progressed in five main areas. First, we have been able to complete modeling runs for historic years of AVHRR data. We have completed runs for the period April-October for the years 1990 through 1994; a five year period of record. We have also completed 1997 runs, and are current with 1998 model results. We are currently completing runs for 1995 to 1996. This historic archive is the essential database needed to calibrate model performance to actual ranges in historic condition for the satellite drought/fire potential index. Second, all model outputs have been posted to an internal web site and documented using Federal Geographic Data Committee (FGDC) metadata standards. The web site is being accessed by a limited number of users from the National Forest System (NFS). Following validation it is our intent to use the web site as the primary technology transfer effort for users of these data. Third, we have installed a dedicated computer and software for processing the AVHRR data. Fourth, we have compiled GIS databases for the State of Alaska and the Boise and Payette National Forests. These GIS's contain geographic records of actual fire occurrence, and will provide the empirical basis for measuring the performance of our model. Efforts are underway to expand those GIS data holdings to other ecoregions across the continental U.S. Fifth, progress in improving model performance, completion of Phase I model runs, and access to the GIS databases have allowed examination of viewing geometry and image compositing effects on model performance. Significant variation in samples of NDVI/Ts values appear to be driven by viewing angle and timing/duration of AVHRR compositing. Additionally, we have recently adapted the U-Maryland Landcover (1KM) database to segment SDI images by biome type in order to test model sensitivity to landcover class, convolution filter size, water/edge effects, as well as image geometry.

Publications and Presentations

"Fire Potential Mapping Using the Advanced Very High Resolution Radiometer." J. Plummer, L. Queen, S. Running, and R. Nemani. Presented to the U.S.D.A. Forest Service Ecological Applications Service Team Research Retreat and Review.

"Enhanced Algorithms for Remote Sensing of Biomass Burning." J. Plummer, L. Queen, W. Hao, D. Ward, and S. Running. Presented at the MT/ID GIS User's Group Meeting, Butte, MT.

"Implementation of EOS Sensor Data Streams to Forest Fire Detection, Monitoring, and Characterization." L. Queen and J. Plummer. Presented to the Alaska Fire Service, Fairbanks, AK.

"EOS-Based Remote Sensing for Forest Fuels Characterization." J. Plummer and C. Seielstad. Interior West Fire Council Conference. Big Sky, MT.

"Using EOS Surface Resistance Logic to Estimate Fire Potential." J. Plummer, L. Queen, and C. Seielstad. Paper to be presented to the American Society for Photogrammetry and Remote Sensing Annual Meeting, Portland, OR.
"Fire Danger Mapping Using AVHRR." J. Plummer, L. Queen, S. Running, and R. Nemani. Proceedings of the Seventh Forest Service Remote Sensing Applications Conference. April, 1998; pp. 396-401.

"Earth Observation for Fire Danger Monitoring." L. Queen. Graduate Seminar presented to the Laboratory for Forest, Nature, and Landscape Research, Leuven University, Belgium.

A map and narrative describing the surface resistance index was published on page 20 of the report "The First EOS Satellite: NASA's Earth Observing System AM-1." NP-1998-03-018-GSFC.

Collaborations Including: NASA Centers, NASA Headquarters, Businessand Industry, Other Federal Agencies, State Agencies
Rocky Mountain Research Station/Intermountain Fire Sciences Laboratory (IFSL). USDA Forest Service, Missoula, MT. A one-year Research Joint Venture Agreement (RJVA) has been signed with the IFSL to use our EOS research to scale estimates of biomass burning in time and space.

University of Alaska Fairbanks and the Alaska Fire Service. The State of Alaska provides three unique opportunities for validation of our SDI model. First, the high latitude provides several satellite overpass opportunities per day; second the Alaska Fire Service has compiled GIS-based databases of actual fire occurrence; and third the scale of biomass burning in Alaska is such that satellite-derived data have suitable resolution to assess fire occurrence and distribution. I have entered into a working relationship with UA and the AFS to share data and validation techniques for Alaska for the 1998 growing season.

Goddard Space Flight Center. As part of our RJVA with the Forest Service, I am collaborating on a project entitled "Biomass Burning and Emissions of Trace gases and Aerosols: Validation of EOS Biomass Burning Products." Investigators include IFSL scientists as well as Y. Kaufman and B. Holben from GSFC. We are developing an AVHRR implementation of two satellite-driven models for fire detection and burn scar characterization. This is a three-year project that started in 1998.

As part of our validation and technology transfer activities we are working with several units of the National Forest System in the Northern Rockies Region One (Lolo NF, Lewis and Clark NF, Flathead NF, Payette NF, and the Boise NF). Through a new post-doc hired using ESIP support, we are distributing our surface resistance maps to fire managers on these forests and are developing user assessment products designed to measure the efficacy of our information products.
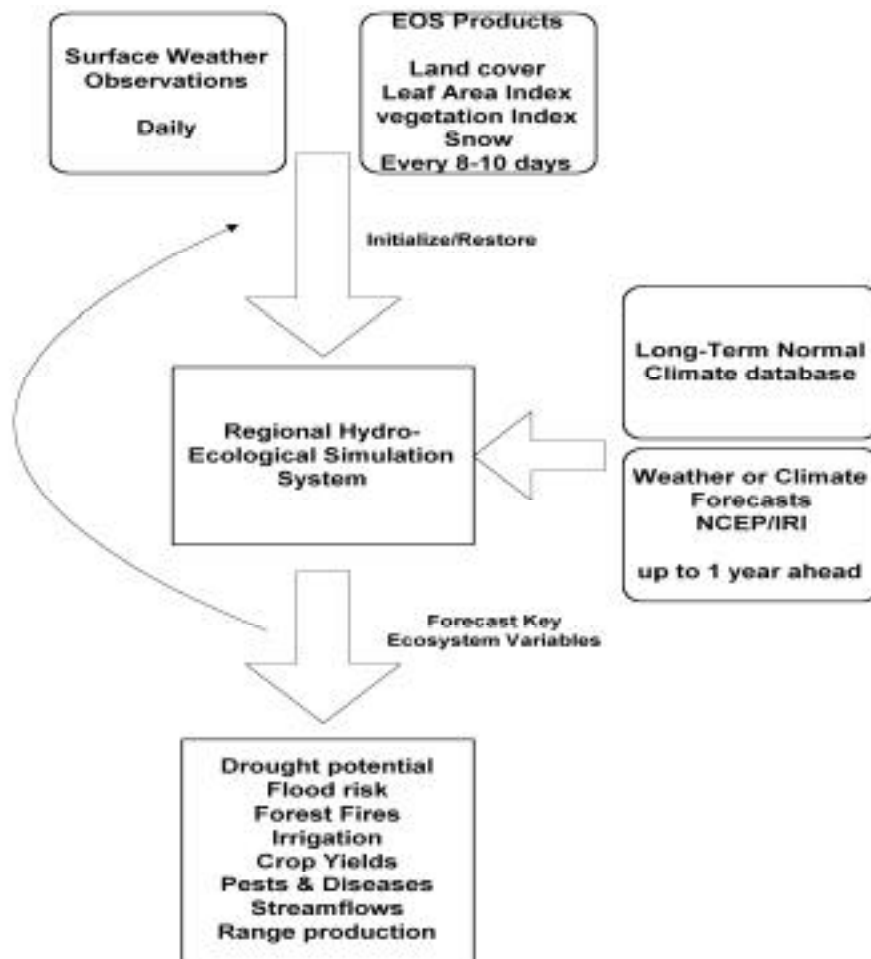
I am a Steering Committee member of the Global Fire Network Planning Committee. This is a group of University, state, and federal employees who are developing strategies for public education and awareness of wildfire issues in the mountain west. This committee is being coordinated by the Continuing Education Program at the University of Montana.

ACTIVITIES of R. NEMANI

I spent much of the year on sabbatical at NASA/Ames Research Center, developing an Ecosystem Forecast System, that would integrate EOS land products (land cover, LAI, snow/ice), conventional weather data and short –long range climate forecasts.

Advanced warnings of the potential changes in key ecosystem variables such as soil moisture, snow pack, primary production and stream flows could enhance our ability to make better socio-economic decisions relating to natural resources management and food production. Forecasting skills of many current coupled Ocean-Atmosphere GCMs have steadily improved over the past decade. Given observed anomalies in SSTs from satellite data, GCMs are able to forecast climatic conditions 6-12 months into the future with reasonable accuracy. While such forecasts are useful for climatological purposes, analysis of their impacts on ecosystem response has been at best subjective.

The Ecosystem Forecast System is designed to estimate key ecosystem variables useful in natural resource management. The proposed system assimilates EOS land products into an ecosystem simulation system, **initialized/restored** with observed weather data and **forced** with short to long-range weather/climate forecasts. The system uses emerging information technologies to automatically gather required input data and disseminate forecast information about the state of ecosystems to user groups. Successful implementation of such a system would bring together state-of-the art technologies in weather/climate forecasting, ecosystem modeling and satellite remote sensing, and would allow better management of floods, droughts, forest fires, irrigation requirements and crop/range/forest production.

Surface Weather Observations

Daily

EOS Products

Land cover
Leaf Area Index
vegetation Index
Snow
Every 8-10 days

Initialize/Restore

Regional Hydro-Ecological Simulation System

Long-Term Normal Climate database

Weather or Climate Forecasts NCEP/IRI

up to 1 year ahead

Forecast Key Ecosystem Variables

Drought potential
Flood risk
Forest Fires
Irrigation
Crop Yields
Pests & Diseases
Streamflows
Range production

Logical flowchart of an Ecosystem forecast System.

MODIS-17/ Net Photosynthesis and Net Primary Production: Algorithm development and parameterization activities – Peter Thornton

Overview

We have established a methodology for parameterizing the Biome Properties Look-Up Table
(BPLUT) that is at the core of the MOD-17 PSN-NPP logic. Figure (bgc_to_mod17) illustrates the method, and it can be summarized as follows:
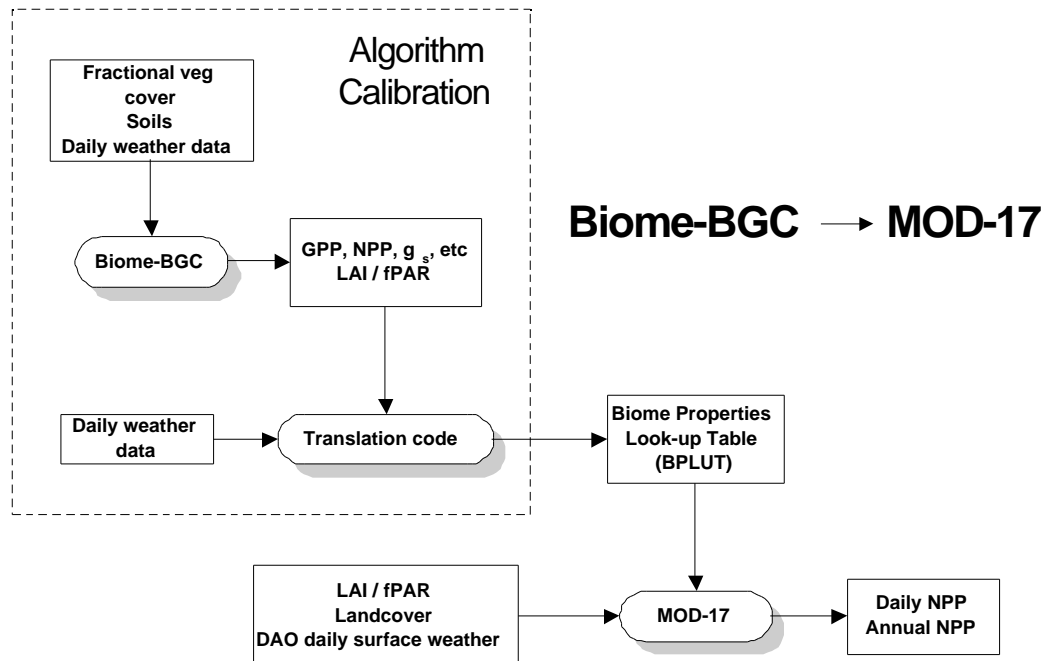
Summary of MOD-17 BPLUT Parameterization Method:
1. Using gridded inputs of fractional vegetation cover, soils data, and daily weather information, Biome-BGC simulations are performed that produce a large output dataset including daily GPP, NPP, stomatal conductance, leaf area index (LAI), fractional absorption of photosynthetically active radiation (FPAR), and soil water content.
2. These Biome-BGC outputs are assessed in conjunction with the landcover and daily weather data to determine the complete set of BPLUT parameters for each vegetation type that minimizes the errors between results from Biome-BGC and MOD-17.
3. The errors associated with translation from Biome-BGC results to MOD-17 results will be determined, and spatial and temporal variation in these errors will be assessed and made available to the research community.

We are parameterizing MOD-17 with the outputs of the process-based ecosystem model Biome-BGC because we feel that Biome-BGC is effective and robust as a distillation of our understanding of terrestrial ecosystem mechanisms. It has been demonstrated to provide accurate representations of carbon cycle dynamics over a wide range of climates and vegetation types. It is not a foregone conclusion that the much simpler and empirical organization of the MOD-17 logic can be made to represent the same dynamics across climates and vegetation types that are present in the Biome-BGC results. The parameterization process will focus on getting the MOD-17 results as close as possible to Biome-BGC, and then carefully documenting the differences, across space, time, climates, and vegetation types.

Each step in this process, as summarized above, is described in greater detail below.

Biome-BGC simulations

We have recently completed a revised version of the Biome-BGC model, including many improvements to the model logic from previous published descriptions. The new model is being tested in a number of different arenas, including the Vegetation/Ecosystem Modeling and Analysis project (VEMAP), the Net Primary Production Data Initiative's Ecosystem Model Data Intercomparison project (NPPDI-EMDI). It has already been successfully applied in the following cases: prediction of carbon and water cycles for the boreal forest, landscape-scale predictions of current and projected future water and carbon cycling for the conifer forests of the central Rockies , predictions of sensitivity to growing season length for deciduous broadleaf forests (White et al., Int J Biomet.); predictions of the net primary production of the global coniferous forest biome (Churkina dissertation); and predictions of the sensitivity to climate changes for the global range of biomes and climates (Churkina et al., Ecosystems).

The basic protocol for the Biome-BGC simulations that are used to parameterize the MOD-17 BPLUT is as follows:
1. Selection of geographic and temporal limits for the simulation, and construction/gathering of required input datasets (landcover, soils, and daily weather data being especially important).
2. Determination of the biome-specific ecophysiological parameters for the vegetation types represented in the landcover input.
3. Spin-up simulations, to bring vegetation and soil pools into equilibrium with climate, under the influence of fire and non-fire sources of mortality/disturbance.
4. Starting from the endpoint of the spin-up runs, a final simulation from which a large volume of diagnostic outputs are saved, for the purpose of BPLUT parameter fitting.

The availability of required inputs varies across temporal and spatial scales. In order to take advantage of the best data resources available at each scale, we

MOD-17 Calibration Exercises
(Biome-BGC simulations)

Spatial extent	Spatial resolution	Duration	Source for weather data
Global	1? x 1?	14 yrs	Scripps
Conterminous U.S.	0.5? x 0.5?	100 yrs	VEMAP (NCAR)
Conterminous U.S.	1 km	17 yrs	DAYMET (NTSG)

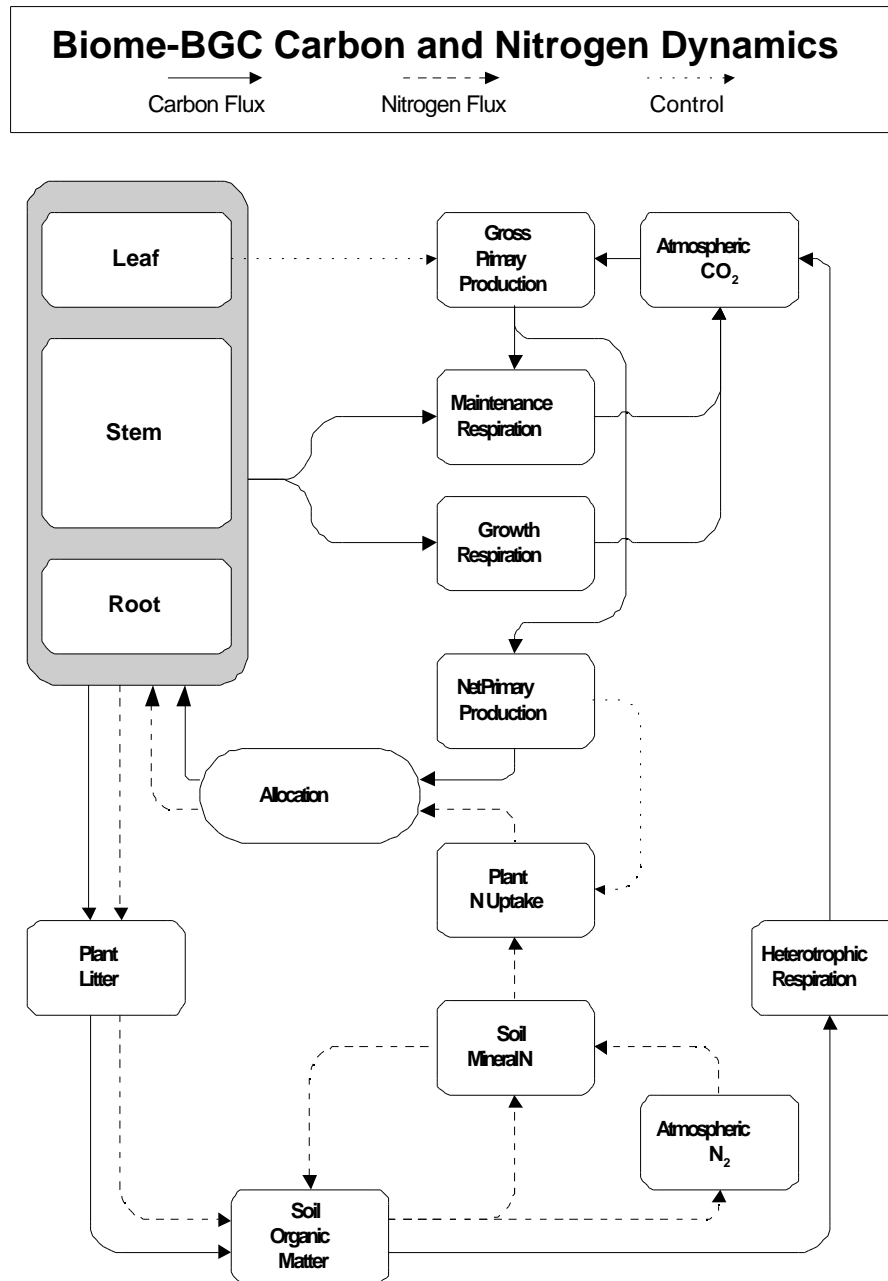are performing a sequence of Biome-BGC simulations at various spatial and temporal scales, as outlined above.

The global runs at 1x1 degree and the conterminous U.S. runs at 0.5x0.5 degree will be done and incorporated in the BPLUT before launch, but the conterminous U.S. 1km runs will not be complete until after launch, at which time we may determine that the BPLUT needs to be updated.

The spin-up runs are an essential component of the parameterization process. Since the climate data used as input to the simulations is of limited duration (14 years of daily data for the global runs), it is necessary to loop through that data multiple times in order to bring the vegetation and soil pools of carbon (C) and nitrogen (N) into equilibrium with the climate. For these simulations, we use a pre-industrial level of atmospheric carbon dioxide concentration, and pre-industrial rates of N deposition, in order to approximate the pre-industrial ecosystem responses to climate variability. From that starting point, CO_2 concentrations are ramped up to the current levels, and current levels of N-deposition are introduced, until finally the current responses of production to climatic variability can be assessed under their likely disequilibrium state. In the process we are generating an data set for preindustrail conditions and current conditions that will provide interesting insight into the global responses to increasing CO_2 and N-deposition, as summarized by the very empirical logic of MOD-17.

The difference between preindustrial and current N-deposition rates is very important to the final BPLUT parameters, since production for many ecosystems was and is N-limited, but changing N-deposition rates is changing the nature of that limitation, and thereby changing the production efficiency, which is reflected in the MOD-17 BPLUT as changes in the production efficiency parameters. The production MOD-17 code will run with only the current parameters, but it will be instructive to run the preindustrial parameters off-line for selected cases.

Capturing the sensitivity of ecosystem production to N-deposition and the interactions of this with climate requires that Biome-BGC incorporate a

mechanistic treatment of the dynamics of C and N in the atmosphere-soil-plant-litter system. The addition of such a treatment is one of the major improvements in the current Biome-BGC logic from previous published versions. Figure (BIome-BGC carbon and nitrogen dynamics) is a simplified schematic of the flows of C and N represented by the model.

Biome-BGC Carbon and Nitrogen Dynamics

Carbon Flux   Nitrogen Flux   Control

Leaf

Stem

Root

Gross Primary Production

Atmospheric CO_2

Maintenance Respiration

Growth Respiration

Net Primary Production

Allocation

Plant N Uptake

Plant Litter

Heterotrophic Respiration

Soil Mineral N

Atmospheric N_2

Soil Organic Matter

Determination of BPLUT parameters

Given the Biome-BGC output and the accompanying landcover and meteorological data, BPLUT parameters will be determined by a simultaneous fitting of all BPLUT parameters in a way that minimizes the differences for daily PSN and annual NPP between Biome-BGC and the MOD-17 logic. The downhill simplex method for non-linear multivariate minimization will be used. This process will be performed for each of the landcover classes represented in the MOD-17 logic. Of the fourteen parameters required in the MOD-17 logic (see MOD17-ATBD), five will be determined by the downhill simplex method. The other nine parameters are exact analogues of ecophysiological parameters that are include in the Biome-BGC simulations, and will simply be copied from those values.

The five numerically determined parameters are: the maximum PAR conversion efficiency (epsilon_max), the minimum and maximum values of daily minimum temperature used to scale epsilon_max (tmin_min and tmin_max), the the minimum and maximum values of vapor pressure deficit used to scale epsilon_max (vpd_min and vpd_max).

MOD-17 is divided into a daily process and an annual process (MOD17 Daily NPP and MOD17 ANNUAL NPP). The daily process shows the influence of Tmin and VPD on the production efficiency, and the derivation of the daily gross priomary production values (GPP). The allometric parameters that come directly from the Biome-BGC logic are illustrated in the second panel of mod17_daily_npp logic, where the calculation of daily leaf and fine root maintenance respiration is related to the input LAI and other ecophysiological and allometric parameters. This figure also illustrates the transfer of information from the daily to the annual MOD-17 logic. In Figure (mod17_annual_npp), the daily outputs are seen as inputs at the top left, and further allometric and ecophysiological parameters are involved in estimating the final annual NPP. The fitted parameters, then, are involved only in the conversion of input FPAR and surface meteorological data to the daily estimates of GPP.

MOD-17 Annual NPP
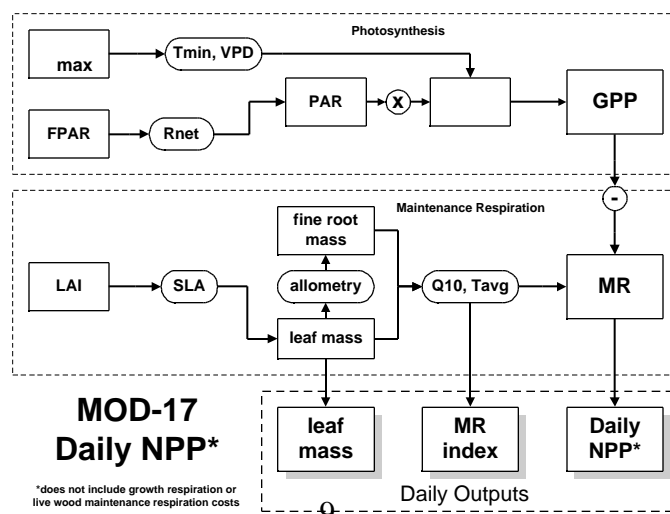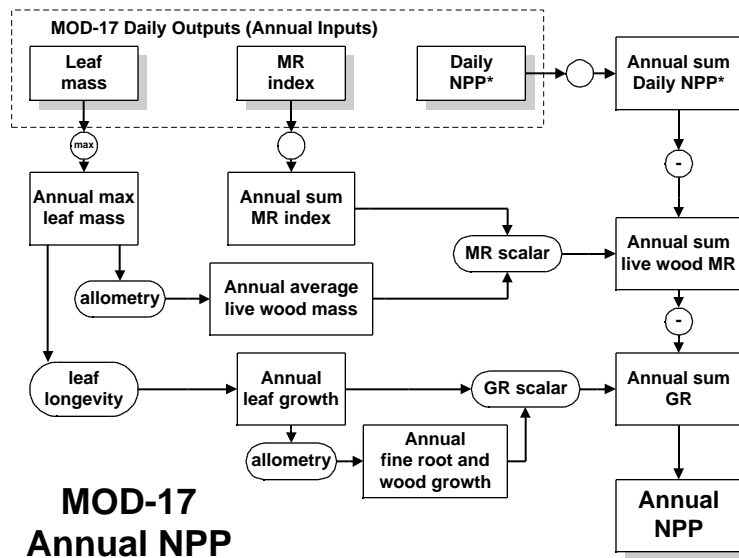
Error assessment

Once the best parameters are selected for the MOD-17 algorithm, the outputs of FPAR and LAI from the Biome-BGC simulations will be used in conjunction with the same daily meteorological data input to Biome-BGC to generate gridded datasets of daily and annual NPP, for comparison with the Biome-BGC results. The purpose of this comparison is to assess the error inherent in the translation from the mechanistic Biome-BGC logic to the much more empirical MOD-17 logic. In that sense, the error statistics will have a diagnostic value equivalent to that of an R^2 derived for a linear regression model: we will use these error estimates to assess the faithfulness of the MOD-17 algorithm in reproducing the results on which it was trained. There are of course a large number of other sources of error in the MOD-17 results that will eventually need to be addressed, but this evaluation will address one important component of the overall error, and allow us to better assess errors arising from other sources. For example, if we find in the translation from Biome-BGC to MOD-17 a strong sensitivity of production to LAI at high values of LAI, and if we also find that the MOD-15 predictions of LAI underestimate the Biome-BGC predictions for high LAI regions, we will be able to use the error statistics from the BGC-MOD-17 translation process to assess the likely total differences and biases between operational MOD-17 results and Biome-BGC results in high LAI regions. The question of which assessment of LAI were more accurate, MOD-15 or Biome-BGC, would still remain, but this analysis would provide a logical foundation for further validation exercises.

ACTIVITIES OF J. M.Glassy, MODIS Software Engineer

OBJECTIVES

My objectives during the time period July 1998 to January 1999 were to:

1) Coordinate development of the new PGE 36,37,38 biome properties lookup table (BPLUT) via a series of Biome-BGC model runs at the SCF.
2) Begin participation in the on-going MODIS "week in a life" (WILT phase II) network and QA operations procedure tests with GSFC MODAPS and LDOPE.
3) Continue development of the Univ.Montana Quality Assurance (QA) toolset, and coordinate with the LDOPE on testing the team wide tools via WILT participation.
4) Begin integrating final source code changes for (PGE 33,34,36,37,38) in anticipation of a final at-launch code delivery in the early March timeframe.
5) Obtain the sources and complete the software build of new generations of the SDPTK and HDFEOS NASA algorithm support libraries.
6) Begin final design and implementation work on our MODIS climate modeling grid (CMG) algorithm variants, (PGEs 39,63 and 64) for FPAR, LAI, PSN, and NPP products, respectively.


WORK ACCOMPLISHED

During the first part of this period, we delivered the full PGE 36,37,38 v.2.0 algorithm suite, which implements the 8-day photosynthesis (PSN) and annual net primary productivity (NPP) products. Version 2.0 of the PGE 33,34 suite (FPAR,LAI) was delivered last quarter. This delivery was immediately followed by plans for a new v.2.1 algorithm generation of both the PGE 36,37,38 (PSN,NPP) algorithm suite as well as PGE 33,34 (FPAR,LAI) algorithms. Details of these changes are covered below under the algorithm specific sections of this report. Note that interested readers can access a complete, cross-referenced set of our SCF MODIS software documentation via the following World Wide Web (WWW) URLs:

*   MOD15A1:
    http://www.forestry.umt.edu/ntsg/projects/global/modis/mod15a1\mod15.htm
*   MOD15A2:
    http://www.forestry.umt.edu/ntsg/projects/global/modis/mod15a2\mod15.htm
*   MOD17A1,2,3:
    http://www.forestry.umt.edu/ntsg/projects/global/modis/mod17/mod17.htm

MOD_PR15A1, MOD_PR15A2: FPAR/LAI 1KM Product

To recap, the MOD_PR15A1 daily FPAR,LAI algorithm software was delivered in April of 1998, followed by a re-delivery in early May, 1998. During this period, we began to identify key revisions to streamline the MOD15 algorithm, made possible by recent new work performed by Dr. Ranga Myneni and his group at Boston University.   This work allows us to simplify our backup algorithm considerably, by eliminating the more complex 732 linear model scheme that required globally distributed ancillary understory and ground cover (8km) data layers. In the new backup scheme, we are able to adequately represent the linear models using just the biome classification code as a single key into two tables of slope and y-intercept coefficients (one for FPAR models, and one for LAI models).

Examples of the V.2.1 1km FPAR and LAI (full 1200x1200 tile) produced from MOD_PR15A2 images are shown below:

LAI (8-day, 1KM)

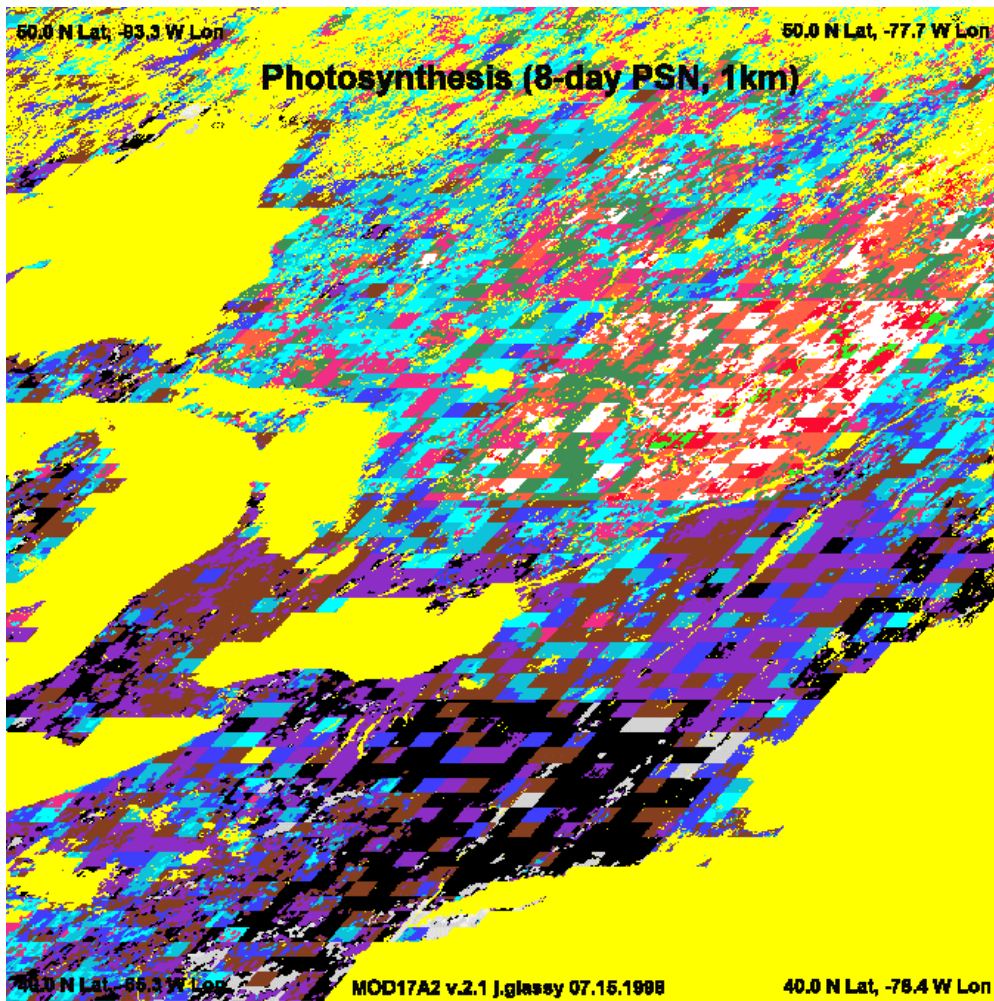MOD15A1 v.2.1 07.16.1998 J. glassy
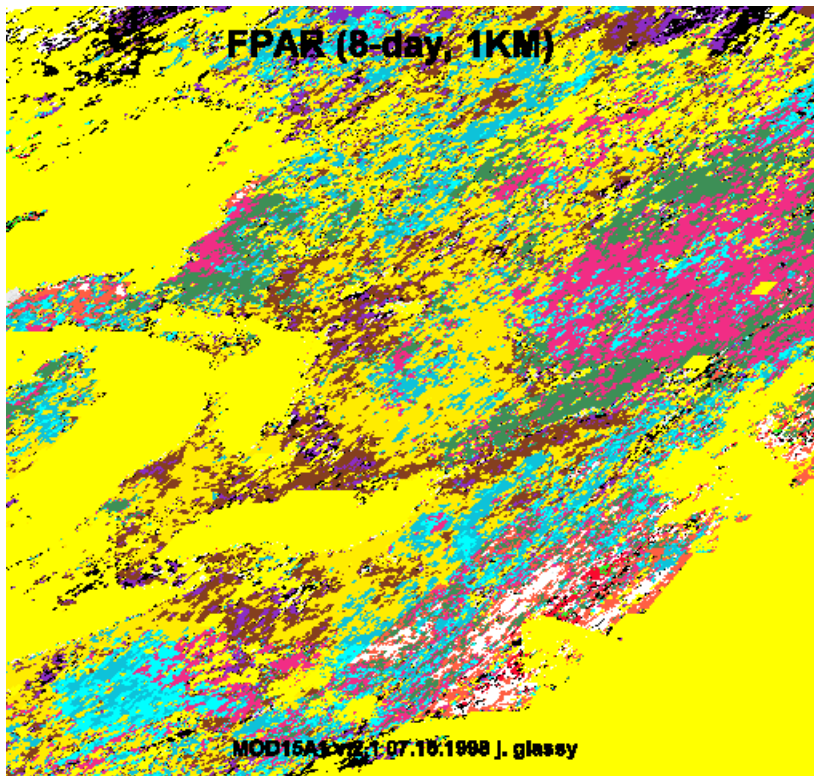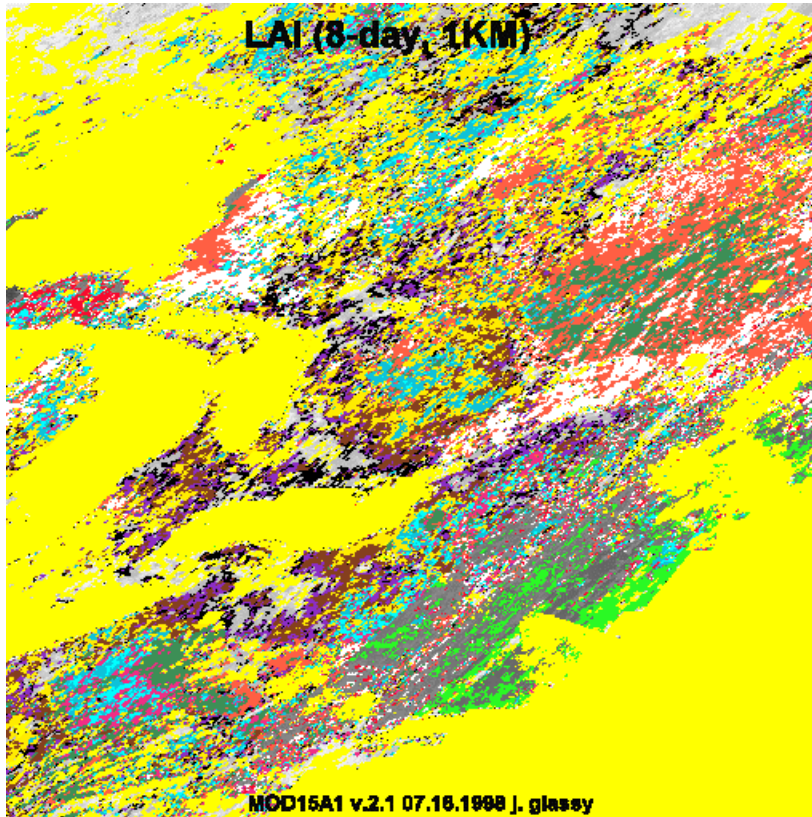
MOD17: PSN/NPP Product

      During this period, the main changes to the PGE 36,37,38 algorithms (MOD17A1, MOD17A2, and MOD17A3) resulted from the evolution of UMD's MOD1Q1 land cover classification scheme from 18 land cover classes to 22. Since MOD17's biome properties lookup table (BPLUT) defines one coefficient record per land cover class, the new BPLUT still in development will now contain 22 records. Recall that in the PGE 33,34 (FPAR,LAI) algorithm, we also use the MOD12Q1, but that in this case, we telescope the 22 classes down to (8) via a simplified correspondence table that addresses the biome types required by the FPAR algorithm. The result is that although both (FPAR,LAI) and (PSN,NPP) algorithms use the same MOD12A1 land cover input, the application (via type translations) of this land cover is different for each algorithm. We are currently at work on the generating the newest biome properties lookup table; this requires a series of Biome-BGC model runs performed locally at our SCF, whose output is refined and translated to the final BPLUT coefficients required.

We continue to rely on two DAO datasets are required for each daily execution of the MOD_PR17A1 process, the "tavg2d" surface climatology 3-hourly timestep data, and the "tsyn2d" energy 3-hourly set. The only key change envisioned involving the climatology data is that the at-launch version is planned to change from a geodetic resolution of 2.0 latitude by 2.4 degrees longitude (91x144 cells/parameter/day) to 1.0 deg latitude by 1.0 longitude (180x360
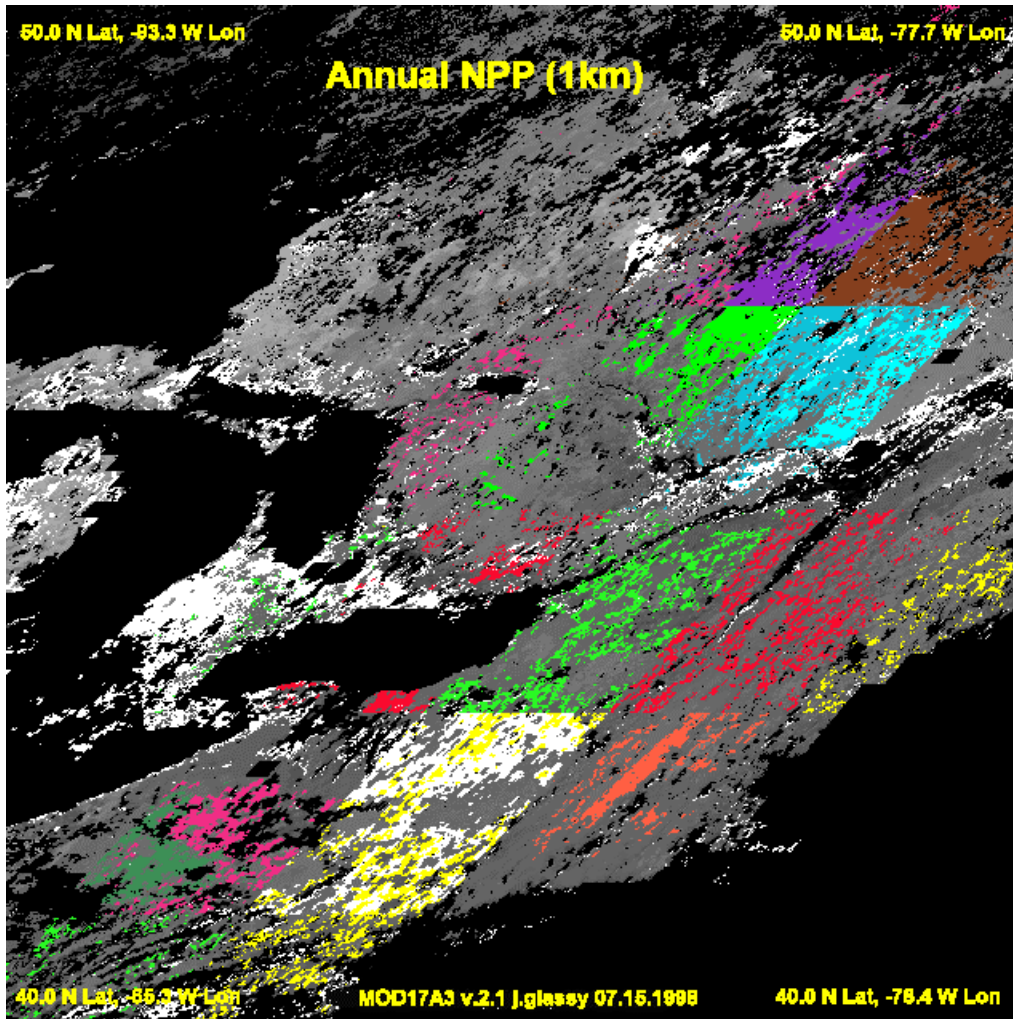
cells/parameter/day). The spatial reprojection facility built into the MOD_PR17A1 algorithm needs no revision to accommodate this change, since it is parameterized using external HDFEOS attribute factors.

Examples of the PSN and NPP 1km products

The geographic minimum bounding rectangle for the test data 1km tile (1200x1200 pixels) is NW: 50.0 N Lat, -93.33 W Lon, NE: 50.0 N Lat, -77.77 W Lon, SW: 40.0 N Lat, -65.27 W Lon, and SE: 40.0 N Lat, -78.35 W Lon. The PSN product example is shown below:

An example of the annual NPP product is shown next:

Annual NPP (1km)

50.0 N Lat, -93.3 W Lon   50.0 N Lat, -77.7 W Lon

40.0 N Lat, -85.3 W Lon   MOD17A3 v.2.1 j.glassy 07.15.1998   40.0 N Lat, -78.4 W Lon

Evolution of the MODIS-University of Montana (MUM) API software library

Version 2.0 of the MOD15 and MOD17 codes were delivered using version 2.0.7 of the MUM API. Minor streamlining changes are planned for the v.2.1 of this API that we anticipate will be delivered in support of the final at-launch codes. Work accomplished during this period including obtaining and building the newest NASA support software libraries (SDPTK v.5.2.4 and HDFEOS 2.4.1). These builds have now been performed on the IBM AIX 4.2.1 platform, the DEC Unix 4.x platform, and the SGI IRIX 6.x compute platform. Changes to the MUM API are planned to include compatibility revisions required for optimum compatibility with these newest support libraries -- SDPTK, now at version 5.2.4, and HDFEOS (now at version 2.4.1).

QA Activity

The major activity during this period involving quality assurance (QA) involved tracking the going development of the new PI processing scheme, under the MODIS Adaptive Processing (MODAPS) facility, and participating in the first MODIS Week-in-a-life (WILT) tests performed via MODAPS and LDOPE. The MODIS Emergency Backup Data Operations System (MEBDOS) was brought up in this period, and we were able to register our SCF as MEBDOS clients and begin testing MEBDOS production facility via some data orders.

Compute Ring (MCR) at the University of Montana SCF

Due to a freeze of our SCF MODIS equipment and supply budget, no additional computation or storage capacity has been added to the University of Montana SCF since the spring of 1997. Our goal remains to bring our aggregate SCF disk store up to between 1 and 1.25 Tb of online disk store, and to add at least one additional compute server. We are currently trying to assess the likely implications of our current capacity shortfall, in the event we must continue to under-fund this area between now and the launch of AM-1 slated for July 15, 1999. One probable result of such capacity limitations is that our response time for identifying and correcting problems identified in our algorithms could lengthen, due to the increased reliance on slower media forms (tape vs disk, in moving data on and off tapes to limited disk staging areas).

MEETINGS ATTENDED

MODLAND/SDST Workshop, September 1998
MODIS Science Team Meeting, December 1998

ON GOING ACTIVITIES

Algorithm Development

During the next period we will primarily concentrate on the following issues:

- Additional internal SCF algorithm testing and verification, using "live" MEBDOS MODIS synthetic data.
- Identifying and attempting to address current shortfalls in the SCF to DAAC and SCF to LDOPE network interface bandwidth.
- The University of Montana has been accepted into the Internet-II consortium and we have applied with NSF for access to the Abilene high speed network. When this comes through, it should provide a significant speed and quality boost to our network interface to NASA, since it represents a base network service level of DS-3.

<u>Data Development</u>

Test data development activities in the next period will focus on developing and/or assembling:
- …a higher quality biome properties lookup (BPLUT) table for MOD17A,A2,A3 (in progress)
- … performing qualitative evaluations of longer contiguous time periods of DAO climatology test
- … a more comprehensive MODIS simulated dataset of 1km aggregated surface reflectances

<u>MODIS UM SCF Compute Ring Infrastructure</u>

Due to a freeze of our SCF MODIS equipment and supply budget, no additional computation or storage capacity has been added to the University of Montana SCF since the spring of 1997. Our goal remains to bring our SCF up to between 1 and 1.25Tb of online disk store, and add at least one additional compute server. We are currently trying to assess the likely implications of our current capacity shortfall, in the event we continue to under fund this area between now and launch of July 15, 1999. One probable result of such capacity limitations is that our response time for identifying and correcting problems identified in our algorithms will lengthen, due to the increased reliance on slower media (moving data on and off tapes to limited disk staging areas).

MODIS related Publications:

1. **Measuring Fractional Cover and Leaf Area Index in Arid Ecosystems: Digital Camera, Radiation Transmittance, and Laser Altimetry Methods**
Michael A. White[1*], Greg P. Asner[2], Ramakrishna R. Nemani[1], Jeff L. Privette[3], Steven W. Running[1] Remote Sensing of Environment (in press)

<u>Abstract</u>: Field measurement of shrubland ecological properties is important for both site monitoring and validation of remote sensing information. During the May 1997 NASA EOS Prototype Validation Exercise (PROVE), we calculated plot-level plant area index, leaf area index, total fractional cover, and green fractional cover with data from four instruments: 1) a Dycam Agricultural Digital Camera (ADC), 2) a LI-COR LAI-2000 plant canopy analyzer, 3) a Decagon sunfleck Ceptometer, and 4) a laser altimeter. Estimates from the LAI-2000 and Ceptometer were very similar (plant area index 0.3, leaf area index 0.22, total fractional cover 0.19, green fractional cover 0.14) while the ADC produced values 5-10% higher. Laser altimeter values, depending on the height cutoff used to establish FT, were either higher or lower than the other instruments' values: a 10cm cutoff produced values ~ 80% higher while a 20 cm cutoff produced values ~30% lower. Violation of LAI-2000 and Ceptometer assumptions by Jornada's sparsely vegetated ecosystem made these instruments primarily useful for

relative within-site plant area index monitoring. Calculation of some parameters required destructive sampling, a relatively slow and labor intensive activity that limits spatial and temporal applicability. Thus, validation/monitoring campaigns should be guided by consideration of the amount of time and resources required to obtain measurements of the desired variables. Our results suggest that the ADC is both efficient and accurate for long-term or large-scale monitoring of arid ecosystems.

2. The impact of growing season length variability on carbon assimilation and evapotranspiration over 88 years in the eastern U.S. deciduous forests. Int. J. Biometeorology (in press).

M.A. White _, S.W. Running, and P.E. Thornton: Numerical Terradynamic Simulation Group, School of Forestry, University of Montana, Missoula MT 59812, USA

Abstract Recent research has suggested that increases in growing season length (GSL) in mid-northern latitudes could be partially responsible for increased forest growth and carbon sequestration. We used the BIOME-BGC ecosystem model to investigate the impacts of including a dynamically-regulated GSL on simulated carbon and water balance over a historical 88-year record (1900-1987) for 12 sites in the eastern U.S. deciduous broadleaf forest. For individual sites, the predicted GSL regularly varied by more than 15 days. When grouped into three climatic zones, GSL variability was still large and rapid. Colder, northern sites showed a recent trend toward longer GSL, but moderate and warm climates did not. Results showed that, for all sites, prediction of a long (short) GSL versus using the mean GSL increased (decreased) net ecosystem production (NEP), gross primary production (GPP), and evapotranspiration (ET).

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3. Increases in surface temperature and growing season length in the high latitudes of western North America.

 A.R. Keyser*, J.S. Kimball, R.R. Nemani, S.W. Running , Submitted to Geophysical Research Letters .

Abstract

We analysed long-term records of surface climate conditions from the North American high latitudes for significant trends in temperature and active growing season length. Thirteen point climate records (mean length = 50 years) show an increase in annual and seasonal average daily temperatures, with spring, March-May, average temperature increase being greatest at 2.31 °C/50yrs. Using river ice breakup as a spatial integrator of spring climate conditions, we found an advance in river breakup date in interior Alaska of seven days per 100 years. These increases in spring temperature result in an average increase in the length of the active growing season of 11.0 days/50yrs.

4. Simulating the effects of climate change on the carbon balance of North American high latitude forests

A.R. KEYSER, J.S. KIMBALL, R.R. NEMANI , and S.W. RUNNING., Submitted to Global Change Biology

Abstract   The large stores of carbon in the vegetation and soils of high latitude ecosystems are a source of significant potential feedback to atmospheric CO_2 concentrations under predicted global warming scenarios. An increase in vegetation net primary productivity would increase this store of carbon; increased decomposition rates could reverse it, making these systems a net source of carbon. Given the large predicted magnitude of warming at high latitudes and the potential feedback of these systems to atmospheric CO_2 concentrations, quantifying both warming and its effects becomes increasingly important. We have analysed long-term (mean length = 50 years) daily, surface meteorological records for thirteen sites in Alaska and northwestern Canada for changes in ecologically sensitive variables. We supplemented these records with an 82 year record of river ice breakup dates for interior Alaska. We found increases in winter and spring temperature extrema for all sites, with the greatest increases in spring minimum temperature averaging 2.35 °C/50yrs. We used these climate records to drive an ecosystem process model, BIOME_BGC, to quantify the effects of climate change on the carbon and water balances of boreal forest ecosystems. The growing season has lengthened an average of 13 days/50yrs due to an advance in leaf onset of 0.11 days/year. This advance in the start of the active growing season correlated positively to progressively earlier ice breakup on the Tanana River in interior Alaska. The advance in the start of the growing season resulted in an average increase in net primary production of 20% over the period of record for both aspen (Populus tremuloides) and white spruce (Picea glauca) stands. Maintenance respiration and evapotranspiration also increased consistently across all sites, but differed in magnitude for aspen and white spruce. Aspen had a greater mean increase in maintenance respiration, 15% versus 10% for spruce. Spruce had a greater mean increase in evapotranspiration, 15% versus 8% for aspen. Average decomposition rates also increased, 17% for aspen and 16% for spruce. The average percent increases in net primary production and decomposition rates are almost equal, indicating that the net ecosystem productivity (NEP) of existing productive stands is not likely to shift significantly with climate change. NEP is most likely to change significantly in areas underlain by permafrost where increases in decomposition will be greater than primary productivity.

basis, GPP differences between the dynamic and mean GSL simulations were larger than NEP differences. As a percent difference, though, NEP was much more sensitive to GSL changes than were either GPP or ET. On average, a one day change in GSL changed NEP by 1.6%, GPP by 0.5%, and ET by 0.2%. Predictions of NEP and GPP in cold climates were more sensitive to changes in GSL than were warm climates. ET showed no similar sensitivity. Our results: 1)

Figure 1. A) Big Delta growing season, slope = 0.383 days/year. B) Breakup date of Nenana River, AK, slope = -0.071 days/year.
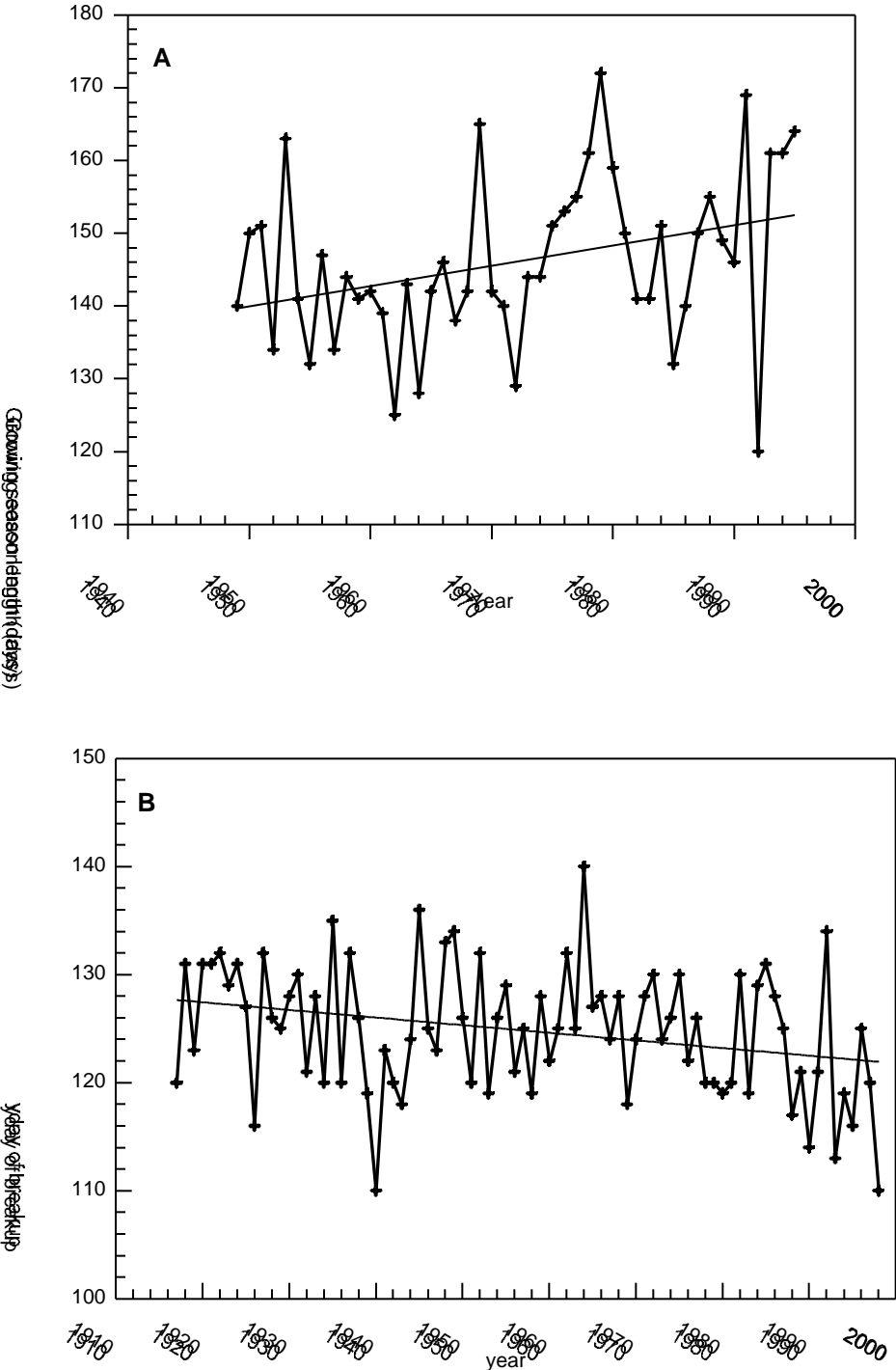
Other Publications:

Waring, R.H. and S.W.Running 1998. Forest Ecosystems: Analysis at Multiple Scales. 2nd Edition Academic Press. 370pp.

Running, S.W., Collatz, J., Washburne, J. and Sorooshian, S. (1998) The ESE Earth Observing System Science Implementation Plan. Chapter 6 Land Ecosystems and Hydrology NASA (in press).

Running, S.W. , RR Nemani and J. Glassy. 1998. GLOBAL NET PHOTOSYNTHESIS AND TERRESTRIAL NET PRIMARY PRODUCTIVITY from the EARTH OBSERVING SYSTEM To appear in Methods in Ecosystem Science, edited by Sala, Jackson, Mooney and Howarth, Springer-Verlag New York, Inc. (in press)

White, J.D., S.W.Running, PE Thornton, REKeane, KCRyan, DBFagre, and CHKey (1998) Assessing regional simulations of carbon and water budgets for climate change research at Glacier Nat Park. USA. Ecological Applications (in press).

Running, S.W. J. S. Kimball and A. R. Keyser, J.B. Way, and K. C. McDonald, S. Frolking R. Zimmerman. (1999) Recent Advances In Satellite Radar Remote Sensing For Monitoring Freeze/Thaw Transitions In Boreal Regions Submitted as a Feature Article for AGU EOS Newsletter.

Hasenauer, H., R. **Nemani**, K. Schadauer and S. Running. 1998. Forest growth response to change climate between 1960-1990 in Austria. Forest Ecology and Management (in press).